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Effect of Spindle Speed and Feed on Material Removal Rate in Turning Operation

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ABSTRACT

The challenge of current manufacturing industries is increase production rate in order to maintain their competitiveness in market.This paper investigates the effect of spindle speed and feed on material removal rate in turning operation execute on conventional lathe machine. An effort has been made to model the one response variable using Taguchi and ANOVA method. Taguchi L9 orthogonal array is used for experimental design.The main aim of this work is save useful production time during manufacturing of product.
Keywords: Turning, Material Removal Rate, Taguchi. ANOVA.

I. INTRODUCTION

In turning operation, material removal rate is key aspect, which has need of attention both from industry as well as researcher. In recent industry, one of the trends is to manufacture low cost, high quality products in less time. On the other hand, material removal rate is another main factor that greatly affects production rate and cost.

Productivity play significant role in today's manufacturing market. Productivity is directly related to the profit level and also goodwill of the organization. Every manufacturing industry aims at producing a large number of products within relatively lesser time. The study aimed at evaluating the best process environment which could satisfy requirements of high productivity.

The purpose of this research work is to find the influence of cutting parameters on material removal rate in turning operation. This paper presents a Taguchi's L9 orthogonal array for the optimization of the material removal rate for turning operation perform on conventional lathe machine. ANOVA (Analysis of variance) is used to find the percentage contribution of each parameter on response variable.

Present work focus on maximize material removal rate with the aim of improving the performance of turning operation. In this research determining process parameters like spindle speed and feed that maximize material removal rate is a most important task for achieving overall economy of machining. Statistical design of experiment refers to the process of planning the experimental so that the proper data can be analyzed by statistical methods, resulting in a valid and reliable outcome.

II. METHODS AND MATERIAL

A. Review of Literature

Das *et al.*[1] presented an optimization method of the cutting parameters cutting speed, depth of cut and feed in dry turning of AISI D2 steel to achieve minimum tool wear, low work piece surface temperature and maximum material removal rate. For this they use three depth of cut range from 0.5 to 1 mm, three feed range from 0.15 to 0.25 mm/rev and three cutting speed range from 150 to 250 m/min and concluded that depth of cut (51.1%) was only found the significant parameter followed by feed (25.5%) on material removal rate. So the optimal combination of cutting parameters for maximum material removal rate was obtained at 250 m/min cutting speed, 1 mm depth of cut and 0.25 mm/rev feed.

Dhabale and Jatti[2] presented use of genetic algorithm to optimize the turning process parameters to obtain maximum material removal rate by taking three spindle speed range from 280 to 1120 rpm, three feed range from 0.05 to 0.15 mm/rev, three depth of cut range from 0.4 to 1.2 mm. Based on single objective optimization by genetic algorithm optimal analysis the best material removal rate value obtained was 6021.411 mm^3/min.

Ghan *et al*.[3] has developed surface roughness and material removal rate prediction model for machining turning and milling of Al-alloy using multi regression analysis for optimization machining parameter. Design of experiment with orthogonal L9 array has been used for conduct the experiment. The experimental data was analyzed by using Minitab16 software. From this study they concluded that most significant parameter on surface roughness are speed and depth of cut while in case material removal rate, speed is most influencing parameter followed by feed but in case of machining time, speed is most influencing parameter followed by depth of cut.

Gupta and Diwedi[4] worked on the effect of insert nose radius and machining parameters including cutting speed, feed rate and depth of cut on surface roughness and material removal rate in a turning operation are investigated by using the Taguchi optimization method. For this work they used three cutting speed range from 100 to 200 m/min, three feed range from 0.25 to 0.3 mm/rev, three depth of cut range from 1 to 2 mm and three nose radius range from 0.4 to 1.2 mm and found that for simultaneous optimization of Surface roughness and material removal rate, depth of cut is the most significant parameter affecting the performance followed by the nose radius.

Kaladhar[5] worked on optimize process parameters on multiple performance characteristics such as, surface roughness and material removal rate during turning of AISI 202 austenitic stainless steel using a CVD coated cemented carbide tool. They investigated the effect of process parameter like cutting speed, feed, depth of cut and tool nose radius on surface finish and material removal rate to obtain the optimal setting of these process parameter. Analysis of variance (ANOVA) and F-tests are used to analyses the influences of cutting parameter during machining. It was found that higher levels of cutting speed, depth of cut, and nose radius and lower level of feed is essential to achieve simultaneous maximization of material removal rate and minimization of surface roughness.

Khatri *et al.*[6] investigated the effect of the spindle speed, feed rate and depth of cut on material removal rate in turning of AISI 1045 steel using uncoated cutting tool in dry condition by using three spindle speed range from 600 to 1000 rpm, three feed range from 0.5 to 1.5 mm/rev and three depth of cut range from 0.15 to 0.25 mm. From this investigation they concluded that the best setting of input process parameters for maximum material removal rate within the selected range are1000 rpm spindle speed, 1.5 mm/rev feed and 0.25 mm depth of cut.

Pawar *et al*.[7] worked on the effect of variation of geometric parameter of insert such as nose radius on surface roughness and material removal rate in a CNC turning operation for high speed steel by using Taguchi method. For this work they use three nose radius range from 0.4 to 1.2 mm, three cutting speed range from 150 to 300 m/min, three feed range from 0.15 to 0.28 mm/rev and three depth of cut range from 0.5 to 0.8 mm and concluded that material removal rate and surface roughness values in CNC turning process is greatly influenced by feed rate and nose radius. Also the optimal level of process parameters for optimum value of material removal rate parameter values are cutting speed 220 m/min, feed 0.28 mm/rev, depth of cut 0.80 mm, nose radius 0.8 mm.

Tayab[8] worked on optimize cutting parameters like spindle speed, feed, depth of cut to minimization of surface roughness and maximization of material removal rate in CNC turning of aluminium alloy(AL 6063-T6) using carbon insert tool in dry condition. Taguchi design of experiment with L9 orthogonal array was used for experiment and minitab17 statistical software used to analysis the experimental data. The ANOVA is used to investigate which design factor and their interaction affects the response significantly. The result show that significant factor for surface roughness are feed rate and spindle speed while for material removal rate, depth of cut and spindle speed are most significant factor.

Uppal *et al*.[9] investigated the influence of cutting conditions on material removal rate during turning of AISI 4041 die alloy steel. Analysis of variance

(ANOVA) is employed to investigate the influence of cutting speed, feed rate, and depth of cut on material removal rate. In this investigation they use three Cutting Speed range from 100 to 300 m/min, three Feed Rate range from 0.2 to 0.6 mm/rev and three depth of cut range from 0.2 to 0.7 mm and concluded that the maximum value of material removal rate is 3.398mm3/sec which is at 300 m/min cutting speed, 0.06 mm/rev feed rate and 0.2 mm depth of cut.

Experimental Methodology

1. Material Selection

Mild Steel is use in present experimental work due to its durability, light weight properties. The work pieces cut for the experiment were of similar dimensions. High speed steel used as tool material due to high hardness, abrasion resistance properties.

2. Experimental Setup

The measurement of material removal rate is done for turning operation perform on the conventional lathe machine shown in Figure 1 and measured by changing the cutting parameters as spindle speed and feed.

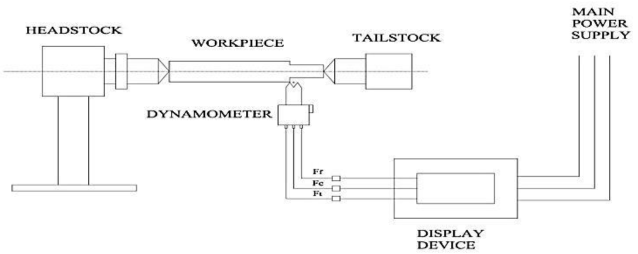

Figure 1: Line diagram of experimental setup

3. Data Collection and Analysis

The experiment involves two cutting parameters (spindle speed and feed) and one response variable (material removal rate) is show in Table 1.

Table 1 Cutting parameters and their different level

Cutting Parameter	Unit	No. of Levels	Values For Each Level		
			Level 1	Level 2	Level 3
Spindle Speed	rpm	3	52	88	150
Feed	mm/rev	3	0.05	0.07	0.10

The experiment work has been performed on conventional lathe machine for different combination of parameters and all the data were collected. In next phase, analysis task is performed over the collected data using statistical technique for optimization of the results.

To determine the effect of each variable on the output, the signal-to-noise (S/N) ratio calculated for each experiment by using Taguchi method in Minitab 17 statistical software and result of total 9 (3x3) runs are given in Table 2. Signal to Noise ratio (S/N) is the ratio of desired parameter to undesired parameter.

Table 2. Material removal rate for different independent parameters

Independent parameter			Dependent variable		
Spindle speed(rpm)	**Feed (mm/rev))**	**Rake angle (degree)**	**Material removal rate (mm^3/min)**	**S/N ratio**	**Mean**
52	0.05	6	377	51.52683	377
52	0.07	6	467	53.38634	467
52	0.10	6	654	56.31155	654
88	0.05	6	401	52.06289	401
88	0.07	6	546	54.74385	546
88	0.10	6	753	57.5359	753

150	0.05	6	466	53.36772	466
150	0.07	6	629	55.97301	629
150	0.10	6	858	58.66975	858

(a) Taguchi method: For this experimental analysis 'The larger is better' category was chosen to reach the optimization conditions for maximization of material removal rate which is the desired condition for production.

Main effects plot for S/N ratio and for Means generated by using MiniTab-17 statistical software as shown in Figure 2 and Figure 3 respectively.

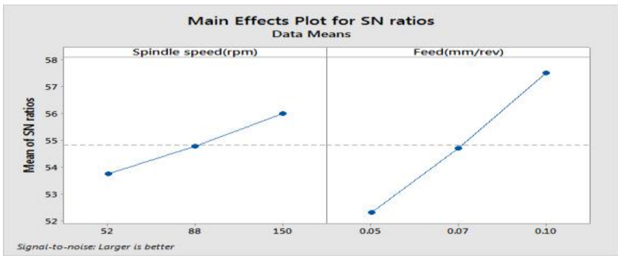

Figure 2: Main effects plot for S/N ratios

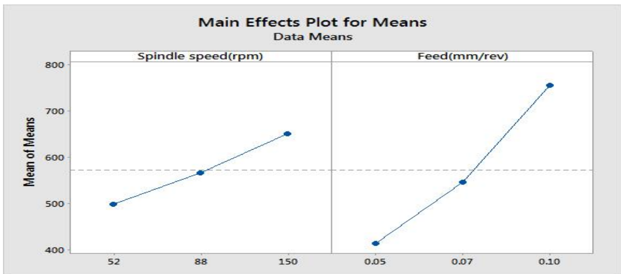

Figure 3: Main effects plot for Means

According to plots the spindle speed should be set to its highest value 150 rpm and feed set to its highest value 0.10 mm/rev for achieving maximum material removal rate.

(b) ANOVA (Analysis of Variance): ANOVA **(**Analysis of variance) table generated for determined percentage contribution of different independent parameters on response variable by using Minitab 17 statistical software is shown in Table 3.

Table 3: Analysis of Variance

Source value	DF	Seq.SS	Contribution	Adj. SS	Adj. MS	F value	P value
Spindle speed (rpm)	2	34649	16.14%	34649	17324.3	19.63	0.009
Feed(mm/rev)	2	176553	82.22%	176553	88276.3	100.01	0.000
Error	2	3531	1.64%	3531	882.7		
Total	6	214732	100%				
S= 29.7097 R-sq= 98.36% R-sq(adj)= 96.71%							

It is clear from this table that the effect of feed and spindle speed on material removal rate is 82.22% and 16.14% respectively. R-sq represents the significance of experiment work.

Regression: Regression equation is formulated to predict the desired material removal rate value. This term is use for finding out the correlation between the data. In the present work, regression equation was obtained by Minitab 17 statistical software.

Material removal rate (mm^3/min) = -75.1 + 1.527 Spindle speed(rpm) + 6816 Feed(mm/rev)

III. RESULTS AND DISCUSSION

The result shows that both two parameters have their effect on the measured material removal rate. The effect of feed is more than spindle speed. Feed is the distance that tool travel in per revolution of work piece, so it indicates the time for cut the material from work piece. Hence for more feed, less time required for cut the material for desired length which increase material removal rate.

It is clear from given data in Table 2 for a constant spindle speed and rake angle, but varying the feed shows more variation in material removal rate. For example, for constant spindle speed 52 rpm and rake angle 6 degree, changing the feed from 0.05 mm/rev to 0.10 mm/rev show increment in material removal rate from 377 mm^3/min to 654 mm^3/min, which is more significant. There is less effect of spindle speed on material removal rate as the increase in spindle speed leads to a less increment in material removal rate.

After analysis of data, it is clear that maximum material removal rate developed at 0.10 mm/rev of feed and at 150 rpm of spindle speed which save energy and useful production time.

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